Lies, Damned Lies and Statistics: How to Make Your Data Say Whatever You Want

by Peter Dong and Joseph Traina

March 3, 2017

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About the course

- Intersession is a one-week period during which students take nontraditional courses
- For the last two years, we have been teaching a course on how statistics can be manipulated to give a desired conclusion
- The goal was not to encourage students to deceive and manipulate, but to train them to recognize statistical deception when it happens

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Misrepresenting with Measures of Middleness

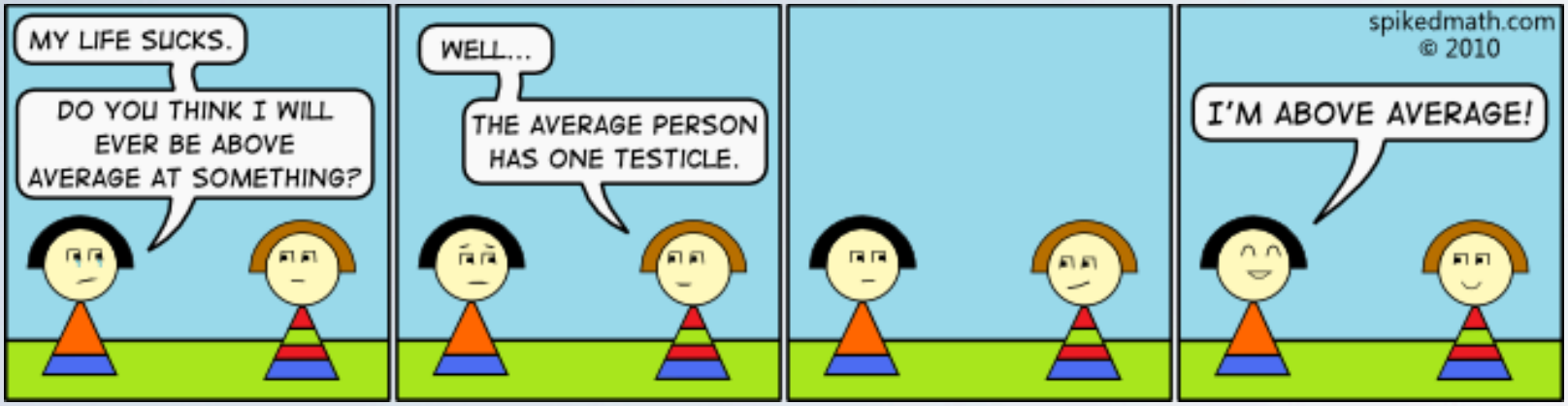

Image Source: http://math-fail.com/2010/04/the-average-person-has-one-testicle-and-one-ovary.html

John earns a score of 27 on the ACT.

- Conclusion: John did exceptionally well on the ACT.
- Rationale: Since the mean ACT score for college-bound Illinois seniors is 21, John has significantly over-performed relative to his peers.

- Conclusion: John did rather poorly on the ACT.
- Rationale: Since John is an IMSA student and the mean ACT score for IMSA students is 32, John has significantly under-performed relative to his peers.

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Student activity: How can it be?

- The employees for Company XYZ are thinking about going on strike. They claim that the typical annual salary for someone with their job is $50,000 (based on national statistics), but the typical employee at Company XYZ makes only $37,500 annually. The company owner does not dispute the national average, but argues that the average annual salary at his company is actually $55,000 (a full 10% higher than the national average). How can they both be correct?

Example adapted from: Huff, Darrell. (1993 reprint). How to Lie with Statistics. W. W. Norton & Company.

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The data

Salaries ($) [Employees Only]
20,000
25,000
35,000
35,000
35,000
40,000
45,000
45,000
50,000
50,000

Mean = $38,000
Median = $37,500
Mode = $35,000
n = 10

Salaries ($) [Employees and Owner]
20,000
25,000
35,000
35,000
35,000
40,000
45,000
45,000
50,000
50,000
225,000

Mean = $55,000
Median = $40,000
Mode = $35,000
n = 11

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Test scores

Exam Scores (%)
83
79
72
94
96
27
91
73
85
84
85

Mean = 79 (C+)
Median = 84
Mode = 85
n = 11

Exam Scores (%) Without outlier
83
79
72
94
96
91
73
85
84
85

Mean = 84.2 (B)
Median = 84.5
Mode = 85
n = 10

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Which is better?

- Mean
- Median
- Mode
- You should examine all of them to make sure you aren't missing anything

What else besides the mean?

Sample 1	*Sample 2*	*Sample 3*
45	0	0
46	10	5
47	20	10
48	30	10
49	40	10
50	50	50
51	60	85
52	70	90
53	80	95
54	90	95
55	100	100

	Sample 1	Sample 2	Sample 3
Mean	50	50	50
Median	50	50	50
Standard Deviation	3.316625	33.16625	43.2435
Standard Error	1	10	13.0384
Range	10	100	100
Minimum	45	0	0
Maximum	55	100	100
Sum	550	550	550
Count	11	11	11
Confidence Level(95.0%)	2.228139	22.28139	29.05138

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Student activity

- You scored 85% on your Advanced Chemistry exam. The teacher mentioned in class that the mean on this exam was 78% and the standard deviation was 3.5%. Your parents are upset that your score was not higher. Use your understanding of measures of variability to make a compelling argument that will convince your parents that your performance on this exam was exceptional.

Presidential politics

- In the table below are the results of three reputable national polls just before the 2000 presidential election. Setting aside issues regarding polling methodology, how should these results be interpreted?

Source: http://faculty.vassar.edu/lowry/polls/poll4.html

Polling Organization	Candidate	Percent Predicted by Poll	Percent Observed in Election
Zogby	Gore	48%	**48.4%**
	Bush	46%	**47.9%**
	Other	6%	**3.7%**
Harris	Gore	47%	**48.4%**
	Bush	47%	**47.9%**
	Other	6%	**3.7%**
Gallup	Gore	45%	**48.4%**
	Bush	47%	**47.9%**
	Other	8%	**3.7%**

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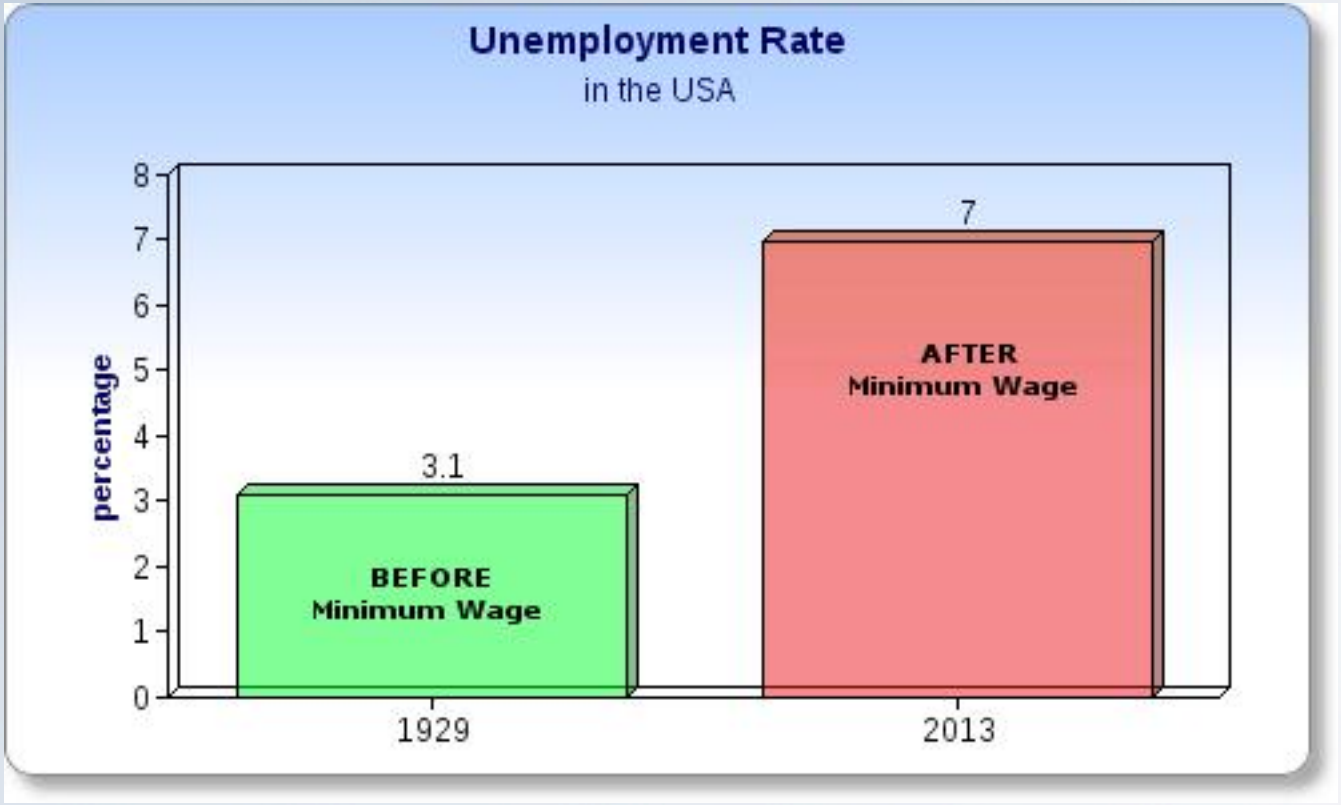
Cherry Picking

Just because it's true doesn't mean it's honest

Image Source: http://www.redhill-cherryfarm.com.au/

Minimum Wage



Source: http://www.debate.org/debates/The-Case-For-the-Minimum-Wage/1/

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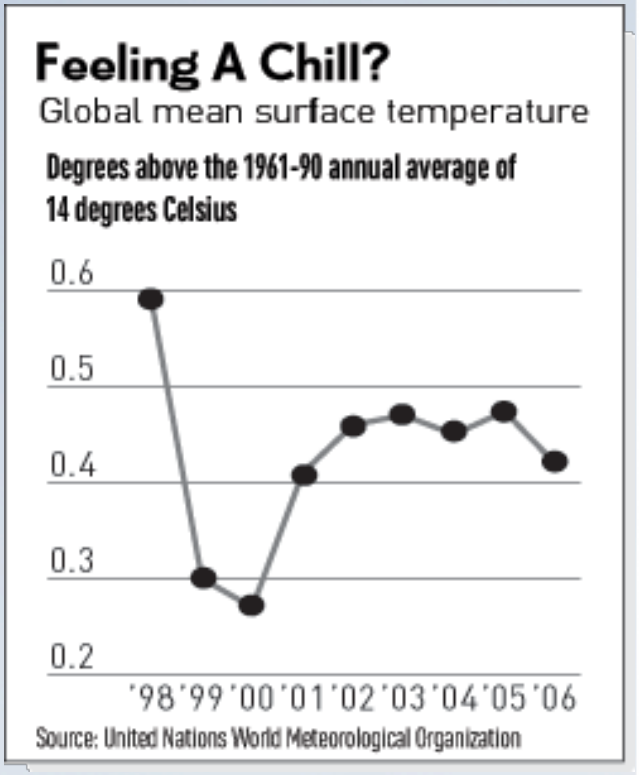
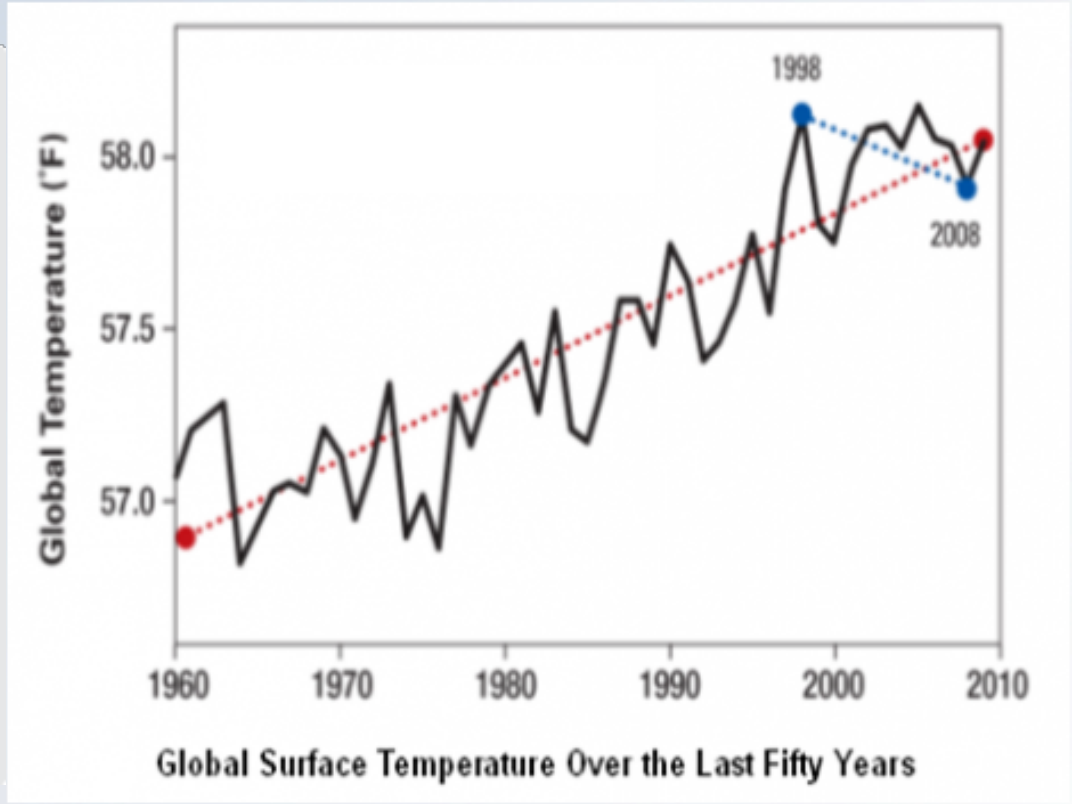
Global cooling





Example from: http://blogs.bu.edu/pbokulic/2012/11/02/cherry-picking-fallacy-of-the-day/

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Movie quotes

- **Film**: *Live Free or Die Hard*.
- **Published blurb**: "Hysterically...entertaining."
- **Actual written line:**

  Jack Mathews, *New York Daily News*:

  "The action in this fast-paced, hysterically overproduced and surprisingly entertaining film is as realistic as a Road Runner cartoon."

Example from: https://en.wikipedia.org/wiki/Fallacy_of_quoting_out_of_context

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Student activity: Quote mining

- Have a contest to create the best quote misinterpretation
- Students should submit the original quote and their mined version, and the class votes on their favorite.
- One example:
  - Mined quote (about the movie “Birdemic”): "It was perfect, in every angle and the visual effects and everything.”
  - Original quote: But, as he said recently, “if it was perfect, in every angle and the visual effects and everything, maybe it wouldn’t be where it is today.”

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Dihydrogen monoxide?

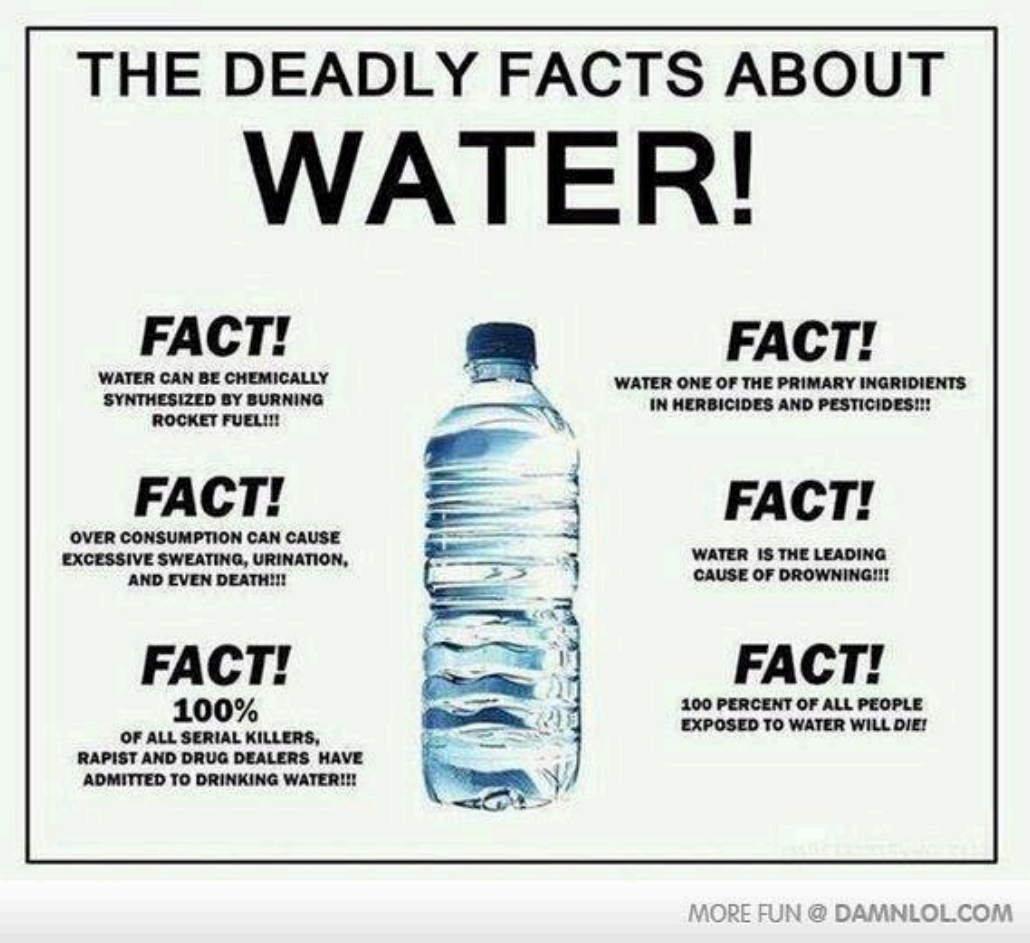

Image Source: https://seanhamptoncole.wordpress.com/2015/08/15/7-logical-fallacies-simplified/

Apples and Oranges

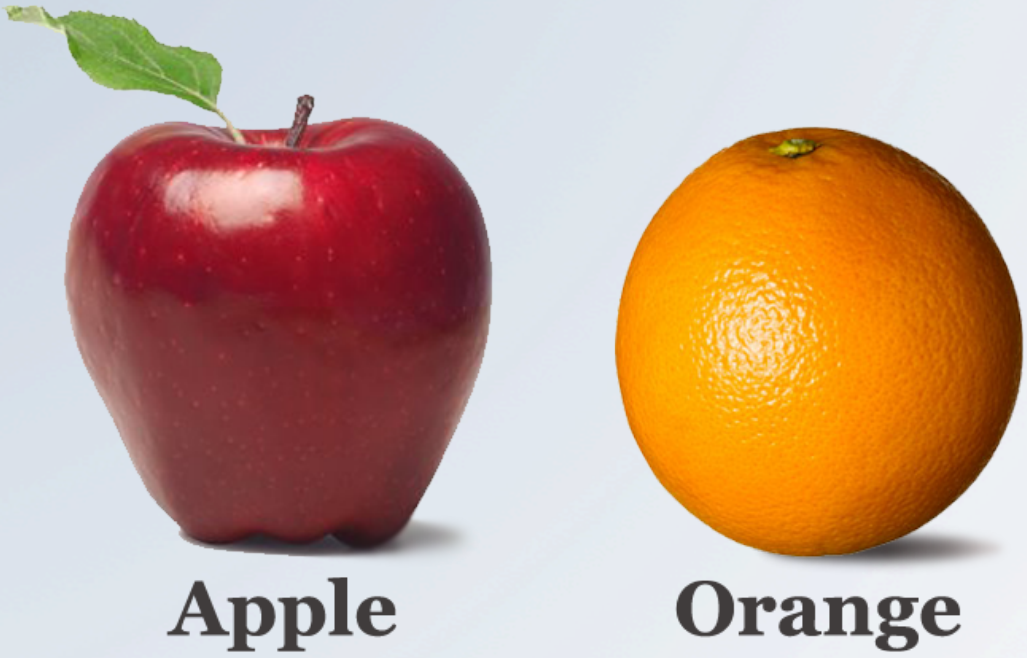

Image Source: https://validissuesnotissues.wordpress.com/2014/09/14/apples-and-oranges/

Join the Navy!

- “The death rate in the Navy during the Spanish-American War was nine per thousand. For civilians in New York City during the same period it was sixteen per thousand. Navy recruiters later used these figures to show that it was safer to be in the Navy than out of it. Assume these figures to be accurate as they probably are. Stop for a moment to see if you can spot what makes them, or at least the conclusion the recruiting people drew from them, virtually meaningless.”

Example from : Huff, Darrell. (1993 reprint). How to Lie with Statistics. W. W. Norton & Company. p. 95.

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Highest grossing movie of all time?

Rank	Movie	Worldwide gross	Year
1	Avatar	$2,787,965,087	2009
2	Titanic	$2,186,772,302	1997
3	Jurassic World	$1,668,984,926	2015
4	Star Wars: The Force Awakens	$1,557,298,252	2015
5	The Avengers	$1,519,557,910	2012
6	Furious 7	$1,515,047,671	2015
7	Avengers: Age of Ultron	$1,405,035,767	2015
8	Harry Potter and the Deathly Hallows – Part 2	$1,341,511,219	2011
9	Frozen	$1,279,852,693	2013
10	Iron Man 3	$1,215,439,994	2013

Source: Guinness Book of World Records via Wikipedia

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Corrected for inflation

Rank	Movie	Worldwide gross (2014 dollars)	Year	Unadjusted Rank
1	Gone with the Wind	$3,440,000,000	1939	216
2	Avatar	$3,020,000,000	2009	1
3	Star Wars	$2,825,000,000	1977	58
4	Titanic	$2,516,000,000	1997	2
5	The Sound of Music	$2,366,000,000	1965	None
6	E.T.: The Extra-Terrestrial	$2,310,000,000	1982	54
7	The Ten Commandments	$2,187,000,000	1956	None
8	Doctor Zhivago	$2,073,000,000	1965	None
9	Jaws	$2,027,000,000	1975	166
10	Snow White and the Seven Dwarfs	$1,819,000,000	1937	None

Source: Guinness Book of World Records via Wikipedia

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By ticket sales

Rank	Movie	Admissions (millions of tickets)	Year	Unadjusted Rank
1	Gone with the Wind	225.7	1939	216
2	Star Wars	194.4	1977	58
3	E.T.: The Extra-Terrestrial	161.0	1982	54
4	The Sound of Music	156.4	1965	None
5	The Ten Commandments	130.0	1956	None
6	Titanic	128.4	1997	2
7	Snow White and the Seven Dwarfs	126.3	1937	None
8	Jaws	120.7	1975	166
9	Doctor Zhivago	120.1	1965	None
10	The Lion King	118.9	1994	25

Source: Estimated in 2012 at http://mrob.com/pub/film-video/topadj.html

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Goofy Games with Graphs!

Seeing is disbelieving

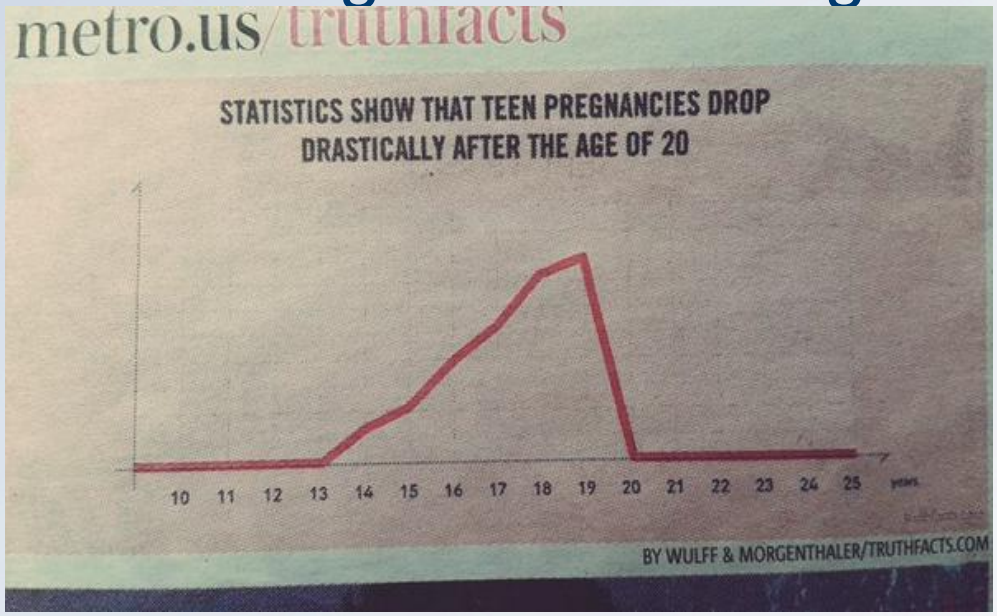
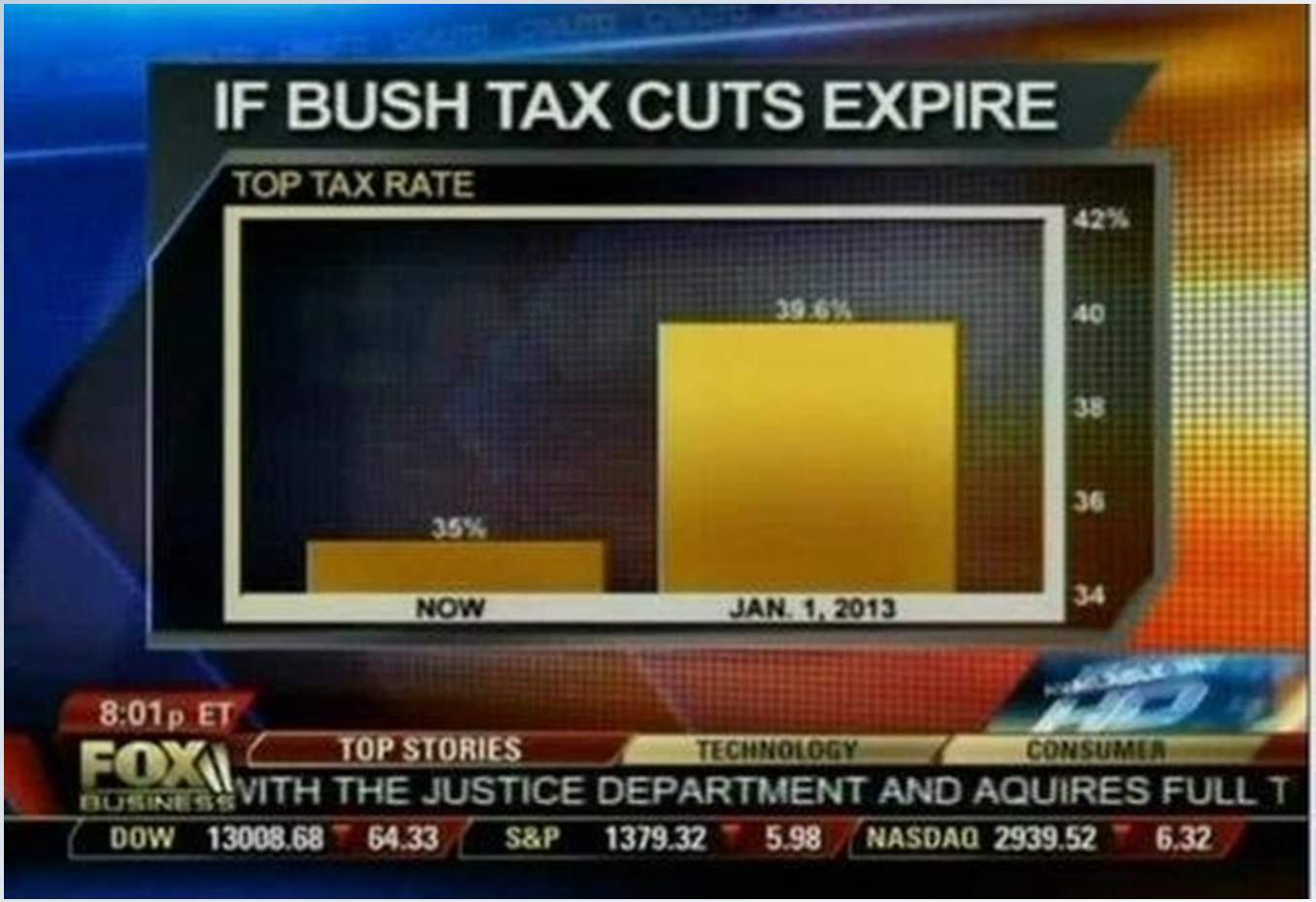


Image Source: http://www.magicalmaths.org/how-graphs-can-be-so-misleading-a-great-starter-worksheet-for-a-data-handling-lesson/

How is this graph misleading?



Example from: http://data.heapanalytics.com/how-to-lie-with-data-visualization/

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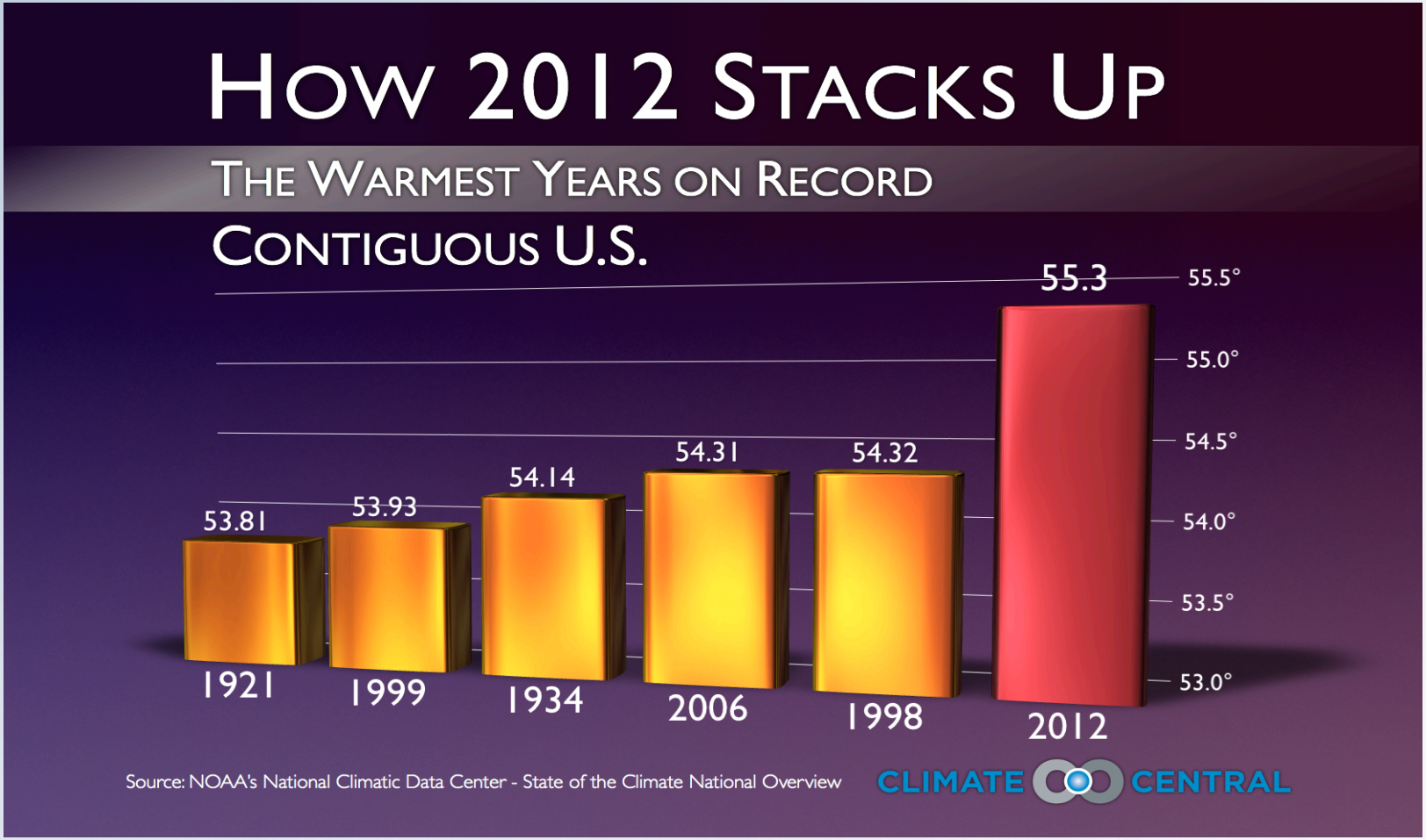
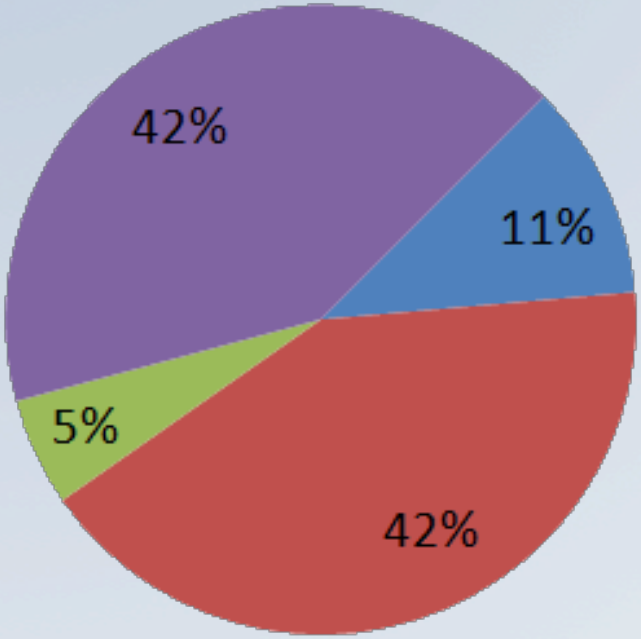
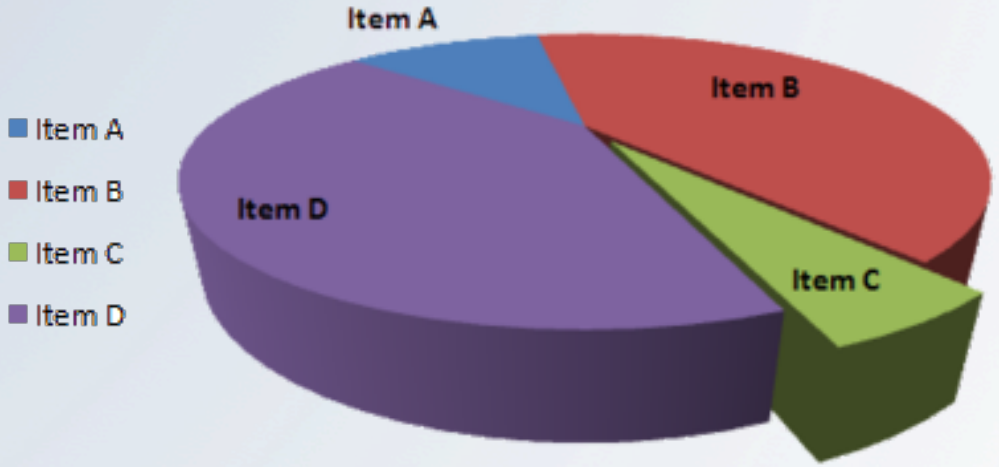
Can you find three ways this graph is misleading?



Source: http://www.climatecentral.org/gallery/graphics/its-official-2012-is-hottest-us-year-on-record

Same figures, but different angles





Example from: https://en.wikipedia.org/wiki/Misleading_graph

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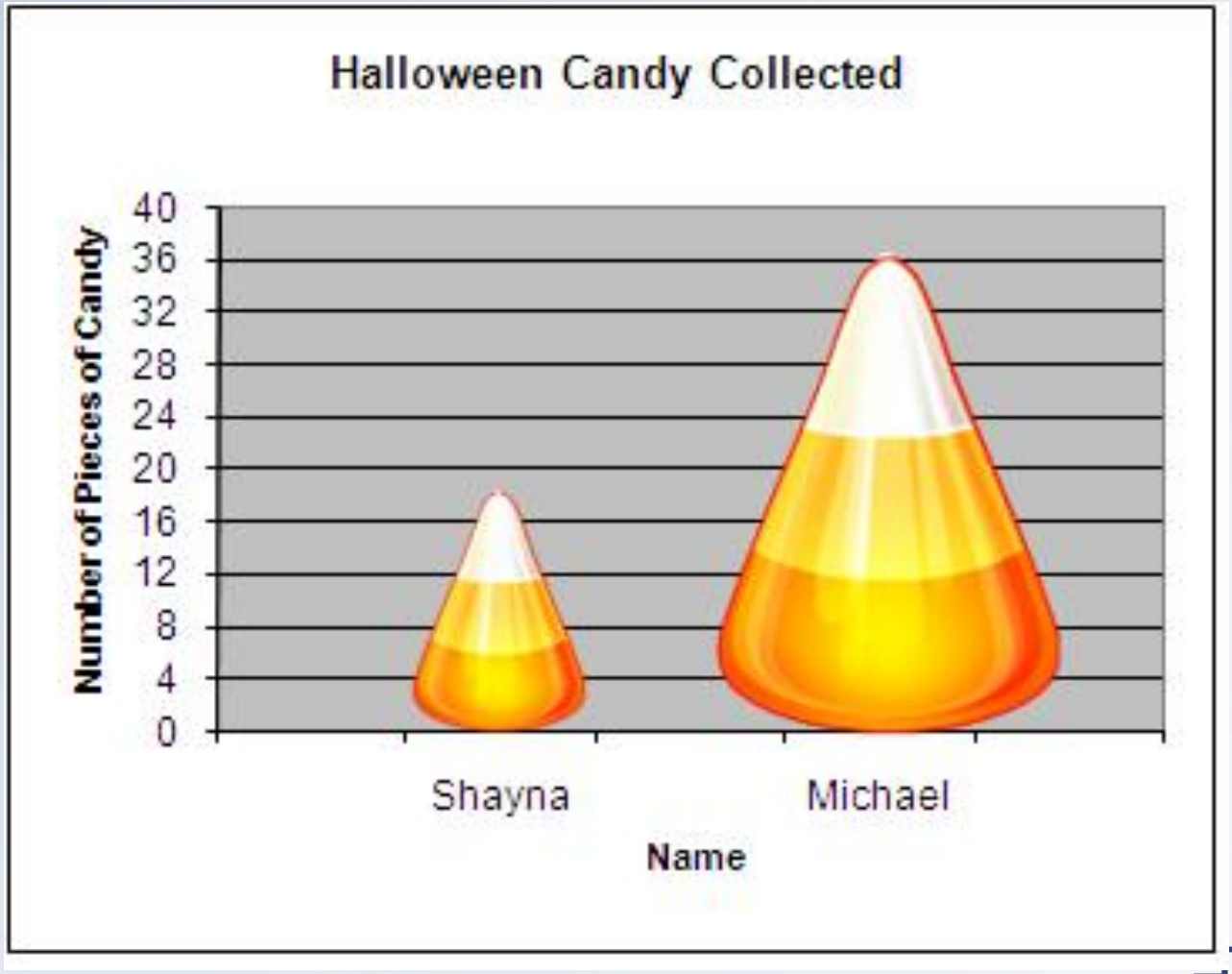
How is this graph misleading?



Example from: http://www.yale.edu/ynhti/curriculum/units/2008/6/08.06.06.x.html

Experimental Design

The Blind Leading the Blind

Image Source: http://www.cafepress.com/mf/48403635/double-blind-study_mugs

Love life

- “Over half of divorcees had doubts on their wedding day and considered leaving their partner at the altar, study reveals”
- “ … 49% of divorcees admitted they were unsure before the ceremony that their marriage would last.”
- “Over half of divorcees considered abandoning their husband or wife-to-be at the altar on their wedding day, a new study has revealed.”

Source: http://www.independent.co.uk/life-style/love-sex/marriage/over-half-of-divorcees-had-doubts-on-their-wedding-day-and-considered-leaving-their-partner-at-the-10313378.html

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Student activity: Design the experiment

- You suffer from frequent headaches. Your friend claims that if you drink his specially formulated "magnetic water," this will cure you of your headache, or at least significantly alleviate your pain. He provides testimonials of others who have had their headaches cured using his magnetic water. He is also willing to sell you some of his specially formulated magnetic water for as little as $10 for a 12 ounce bottle.
- You are skeptical of your friends claim and the supposed miraculous healing properties of his magnetic water. How would you design an experiment to test the effectiveness of this "magnetic water?"
- [Note: You may assume that costs and resources are not an issue.]

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Things to consider

- There must be a control group
  - With regular water?
  - With nothing at all?
  - With an analgesic?
- The subjects must be blinded (they don't know whether the water is regular or magnetic)
  - How could you blind subjects if you used nothing as a control?
- How do you know it was effective?
  - How do you report headache pain?
  - Double-blinding is also important (those recording the data also don't know whether subjects had regular or magnetic water)
- What sample size is appropriate?
- How do you find your sample?
  - Does asking only people who suffer from frequent headaches introduce bias?
  - How do you assign subjects to different groups?

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Placebo effect (“I will please”)

- “Also called the placebo response. A remarkable phenomenon in which a placebo -- a fake treatment, an inactive substance like sugar, distilled water, or saline solution -- can sometimes improve a patient's condition simply because the person has the expectation that it will be helpful.”
- “The scientific study of the placebo effect is usually dated to the pioneering paper published in 1955 on ‘The Powerful Placebo’ by the anesthesiologist Henry K. Beecher (1904-1976). Beecher concluded that, across the 26 studies he analyzed, an average of 32% of patients responded to placebo.”
- “People who receive a placebo may also experience negative effects. They are like side effects with a medication and may include, for example, nausea, diarrhea and constipation. A negative placebo effect has been called the nocebo effect.”

Information from: http://www.medicinenet.com/script/main/art.asp?articlekey=31481

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Blindness

- *"Nature* published an article in 1988 that shocked the scientific community in that it provided experimental support for homeopathy … or did it?"
- "The article was published with the following disclaimer: 'Editorial reservation: Readers of this article may share the incredulity of the many referees … Nature has therefore arranged for independent investigators to observe repetitions of the experiments.' "
- "Finding of independent investigation: There was some degree of subjectivity in determining whether or not white blood cells exhibited an allergic response. Additionally, the researcher who measured this response knew in advance which test tubes had been treated with the homeopathic remedy. When this information was hidden from that researcher in repeated trials, the homeopathic remedy was found to be no more effective than the control."

Information from: Singh & Ernst. (2008). Trick or Treatment. W. W. Norton & Company. pp.118-122.

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Survey Silliness

The public is always right

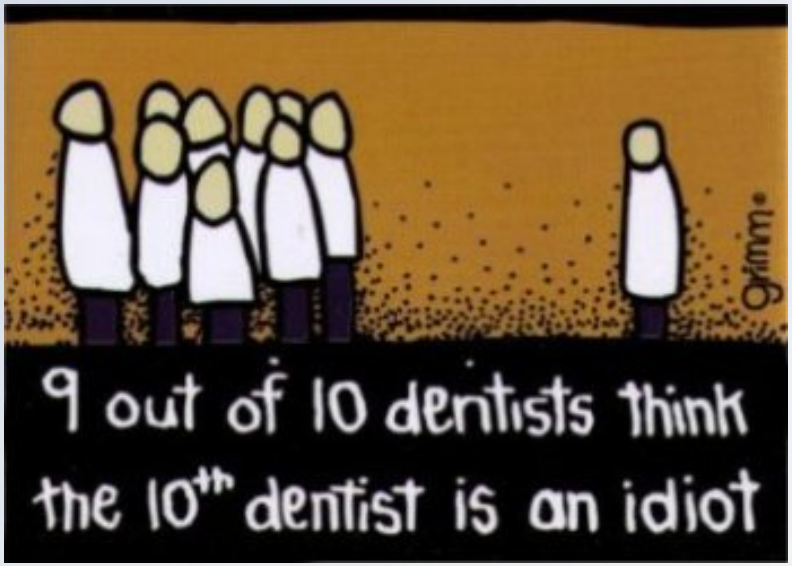

Image Source: https://www.pinterest.com/kathyodendahl/dental-humor/

Student activity: What do you think?

- Let's assume that IMSA surveys former students from the Classes of 1990-2000 and asks them how much money they make per year. Over 200 students respond to the survey, and the results show that the average annual income for a former IMSA student is $150,000. Do you think this number is accurate? Why or why not?

Example adapted from: Huff, Darrell. (1993 reprint). How to Lie with Statistics. W. W. Norton & Company.

Who won the debate?

- Most political pundits reported that Hillary Clinton won the October 13, 2015 Democratic presidential debate. Also, a "poll, conducted via automated telephone calls by research firm Gravis Marketing (**One America Network**, 10/14/15), found that 62 percent thought Clinton won, while 30 percent gave it to Sanders. The poll … is described as a 'random survey of 760 registered Democratic voters across the US …' ".
- "Adam Johnson, associate editor at **AlterNet** and frequent **FAIR.org** contributor, pointed out (**AlterNet**, 10/14/15) that not only had Sanders won every online poll 'by at least an 18-point margin,' he also was picked as the winner by various media-convened focus groups."
- How can such inconsistencies exits with respect to the outcome of the same debate?

Source: http://fair.org/home/pundits-thought-clinton-beat-sanders-but-did-viewers/

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An activity in survey bias

Answer the following questions

- Some of you were asked:
  - Did Gandhi die before or after the age of 90?
  - How old was Gandhi when he died?

    (Closest guess gets a prize.)
- Others were asked:
  - Did Gandhi die before or after the age of 50?
  - How old was Gandhi when he died?

    (Closest guess gets a prize.)

Questions adapted from: Strack, F. and Mussweiler, T. (1997). Explaining the enigmatic anchoring effect: Mechanisms of selective accessibility. *Journal of Personality and Social Psychology, 73* (3), 437–446.

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Anchoring Effect

- Scenario 1
- When students were asked if Gandhi died before or after the age of 90, and then were asked immediately afterward to guess Gandhi's age when he died, the mean response was 82 years.

- Scenario 2
- When students were asked if Gandhi died before or after the age of 50, and then were asked immediately afterward to guess Gandhi's age when he died, the mean response was 63 years.

(t = 3.1, df = 20, p = .006; effect size d = 1.3)

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Biased or leading questions

- Would you vote for a woman for president if she were qualified in every other way?
- Don't you think that teachers are paid too little?
- Do you think the war in Iraq is a worthy cause or a hopeless cause?
- How would you rate the career of legendary outfielder Joe Dimaggio?
- What is your opinion of Crazy Justin's auto-repair?
  - Pretty good
  - Great
  - Fantastic
  - Incredible
  - The Best Ever

Source: Taken from Triola, Essentials of Statistics. Addison Wesley.

A student assignment

- Get into assigned groups of 3-4 people.
- Choose a controversial topic of interest to many students.
- Write an unbiased survey question on that topic. [Note: Your survey question must be school-appropriate.]
- Then write a biased version of that same survey question. [Note: The biased version should be written so as to skew the responses toward a predetermined result.]
- Survey at least 20 IMSA students with each being randomly assigned to answer either the unbiased or biased question.
- Be prepared to share your survey questions and results during class tomorrow.

Fabulous Fallacies

It must be true: I read it on the Internet.

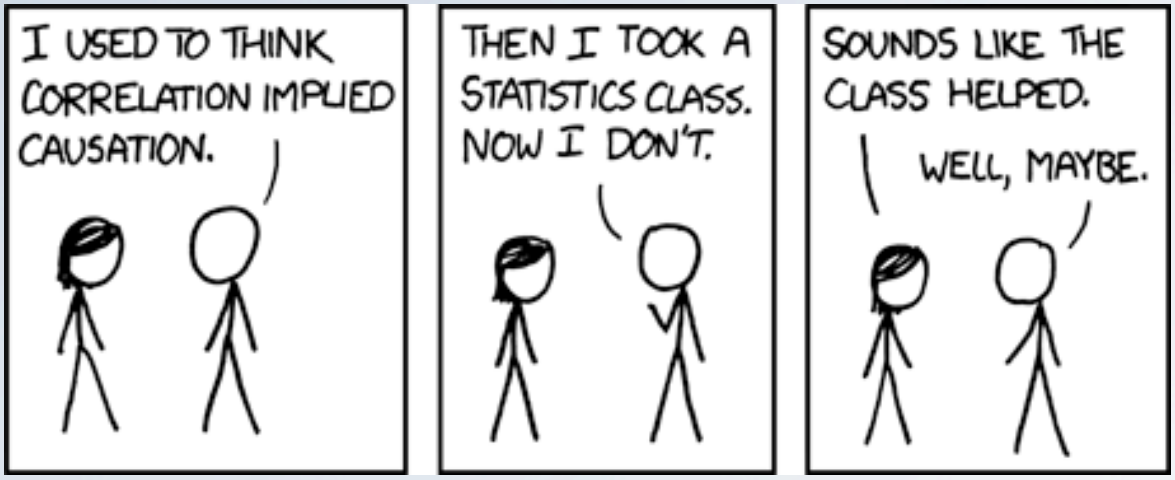

Image Source: http://theconversation.com/clearing-up-confusion-between-correlation-and-causation-30761

Correlation and causation

- Correlation fallacy: *Assuming a cause and effect relationship between two variables simply because they are correlated.*
- Note: Correlation does not prove causation!
- Examples of Spurious Correlations:
  http://www.tylervigen.com/spurious-correlations

Post hoc ergo proctor hoc

- *"After this, therefore because of this" [Assuming A caused B simply because B occurred just after A]*

Example 1

The only policy that effectively reduces public shootings is right-to-carry laws. Allowing citizens to carry concealed handguns reduces violent crime. In the 31 states that have passed right-to-carry laws since the mid-1980s, the number of multiple-victim public shootings and other violent crimes has dropped dramatically. Murders fell by 7.65%, rapes by 5.2%, aggravated assaults by 7%, and robberies by 3%.

Source: "The Media Campaign Against Gun Ownership", *The Phyllis Schlafly Report*, Vol. 33, No. 11, June 2000.

Example 2

… [E]vidence shows that even state and local handgun control laws work. For example, in 1974 Massachusetts passed the Bartley-Fox Law, which requires a special license to carry a handgun outside the home or business. The law is supported by a mandatory prison sentence. Studies by Glenn Pierce and William Bowers of Northeastern University documented that after the law was passed handgun homicides in Massachusetts fell 50% and the number of armed robberies dropped 35%.

Source: "Fact Card", Handgun Control, Inc.

Examples from: http://www.fallacyfiles.org/posthocf.html

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The statistical fallacy

- Also called a fallacy of division
- *The application of statistical statements to individuals*
  - Studies find that men make more money than women.
  - Therefore Dr. Dong makes more money than Dr. Dahleh.
- A more complex, but more common, example
  - Studies show that putting more people in prison does not reduce crime
  - Thus, if you lock away criminals, other people will commit more crimes to keep the amount of crime the same
- Beware of sociology and education studies
  - Some studies show that use of computers in classrooms improves student learning
  - Therefore, when you use a computer in a classroom, you must be improving your learning

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Appeal to popularity

- *Judging the strength of an argument or claim based on how many people support or believe it.*
- Example: “A 2005 Gallup Poll found that an estimated 25% of Americans over the age of 18 believe in astrology—or that the position of the stars and planets can affect people's lives. That is roughly 75,000,000 people. Therefore, there must be some truth to astrology!”

Example from: http://www.logicallyfallacious.com/index.php/logical-fallacies/40-appeal-to-popularity

- Note: There was once a time when nearly everyone was convinced the world was flat, but that didn’t make it true.

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Anecdotal Evidence

- *Evidence based on an isolated example or personal experience*
- *An extremely weak, but frequently used form of evidence that often has a surprisingly strong influence on people.*

- *Examples:*

  - Cigarettes don't cause cancer. My uncle smoked a pack of cigarettes every day for 40 years, and he never got lung cancer or any other kind of cancer.

  - *MassBlaster* is a dietary supplement that really works. I lost 20 pounds after I starting taking a *MassBlaster* pill with every meal.

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Final assignment

- Get into your previously formed groups of 3-4
- Your job is to use data and statistics to disprove something well-known, or to prove something that is incorrect
- Feel free to use as many of the errors we covered as you wish
- Make sure to include visuals (e.g., graphs)
- Create a PowerPoint presentation to summarize your findings
- Your presentation should be 5-10 minutes in length
- Teachers can make the assignment more specific by requiring the topic to be in a certain field, such as athletics, education, or economics

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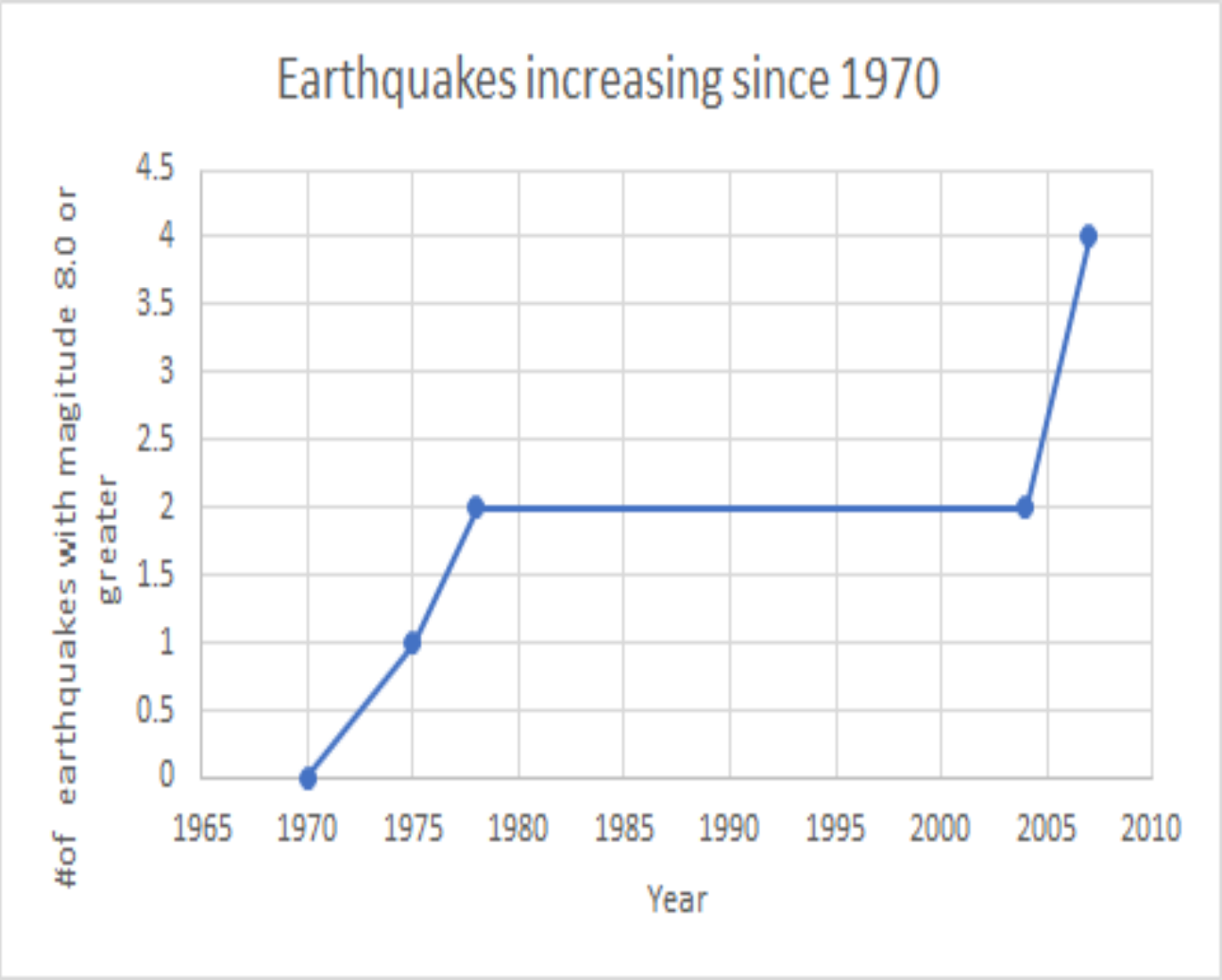
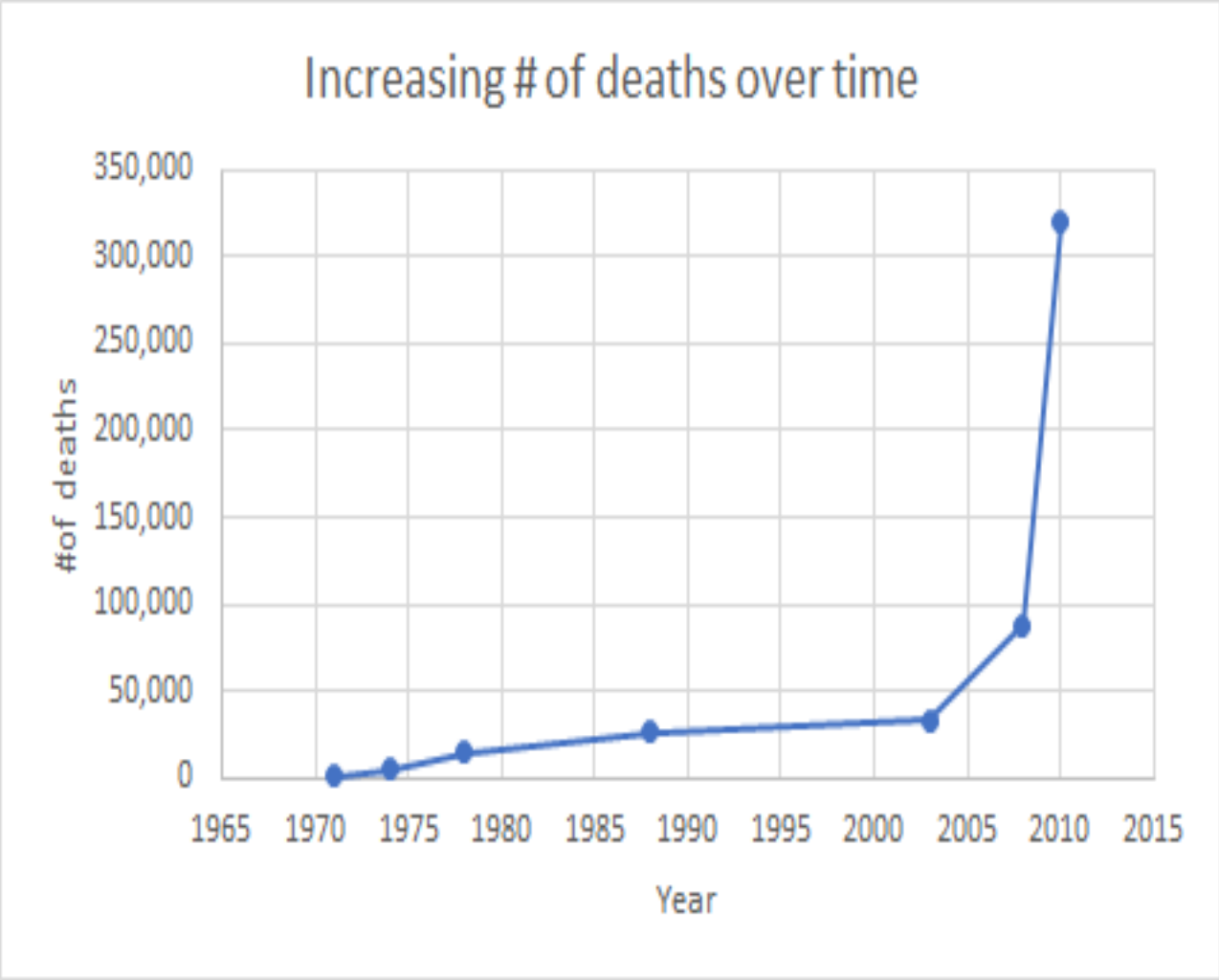
Student examples

Some of our favorite deliberately misleading figures

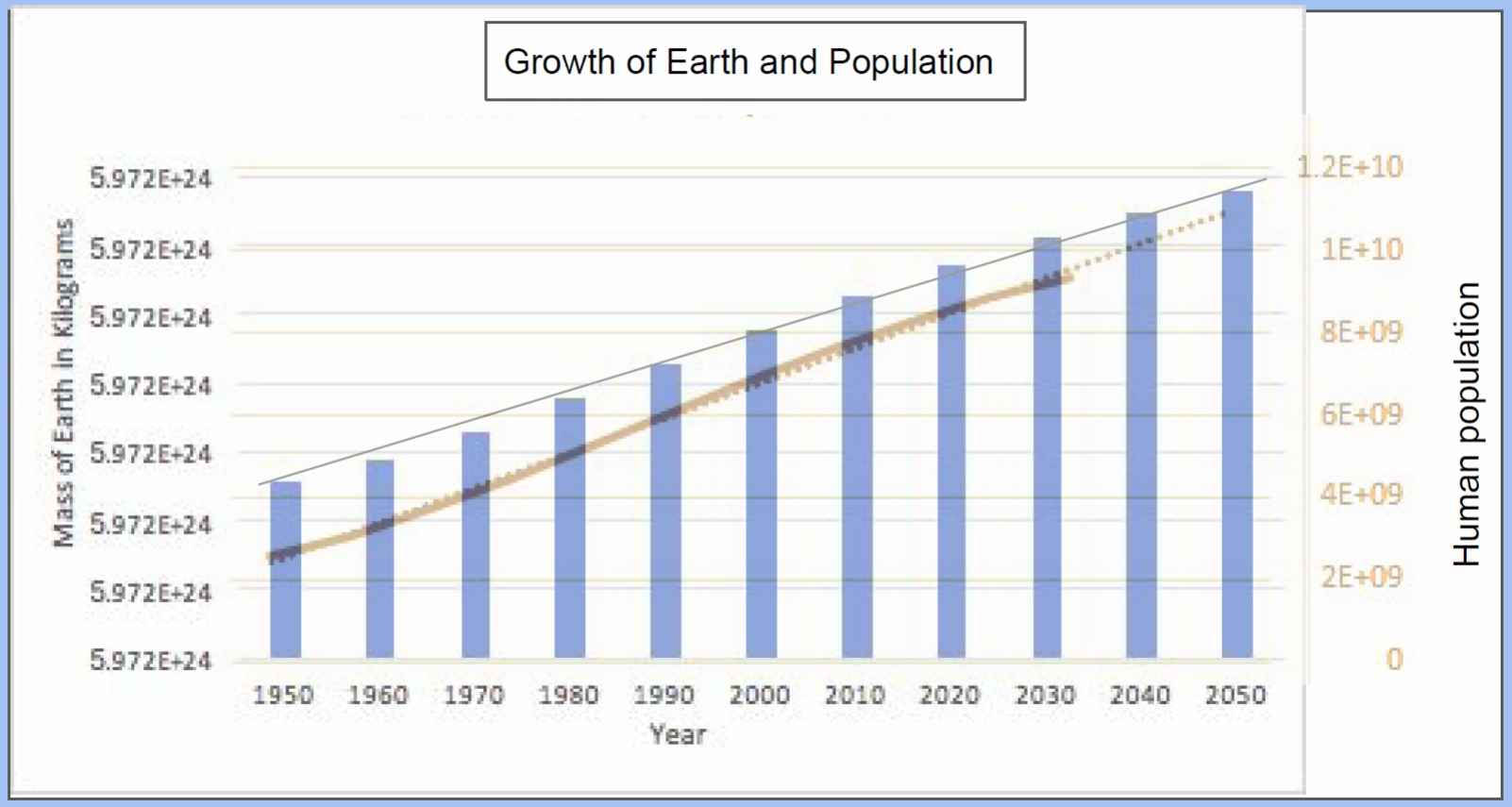
Earthquakes of greater magnitude are increasing



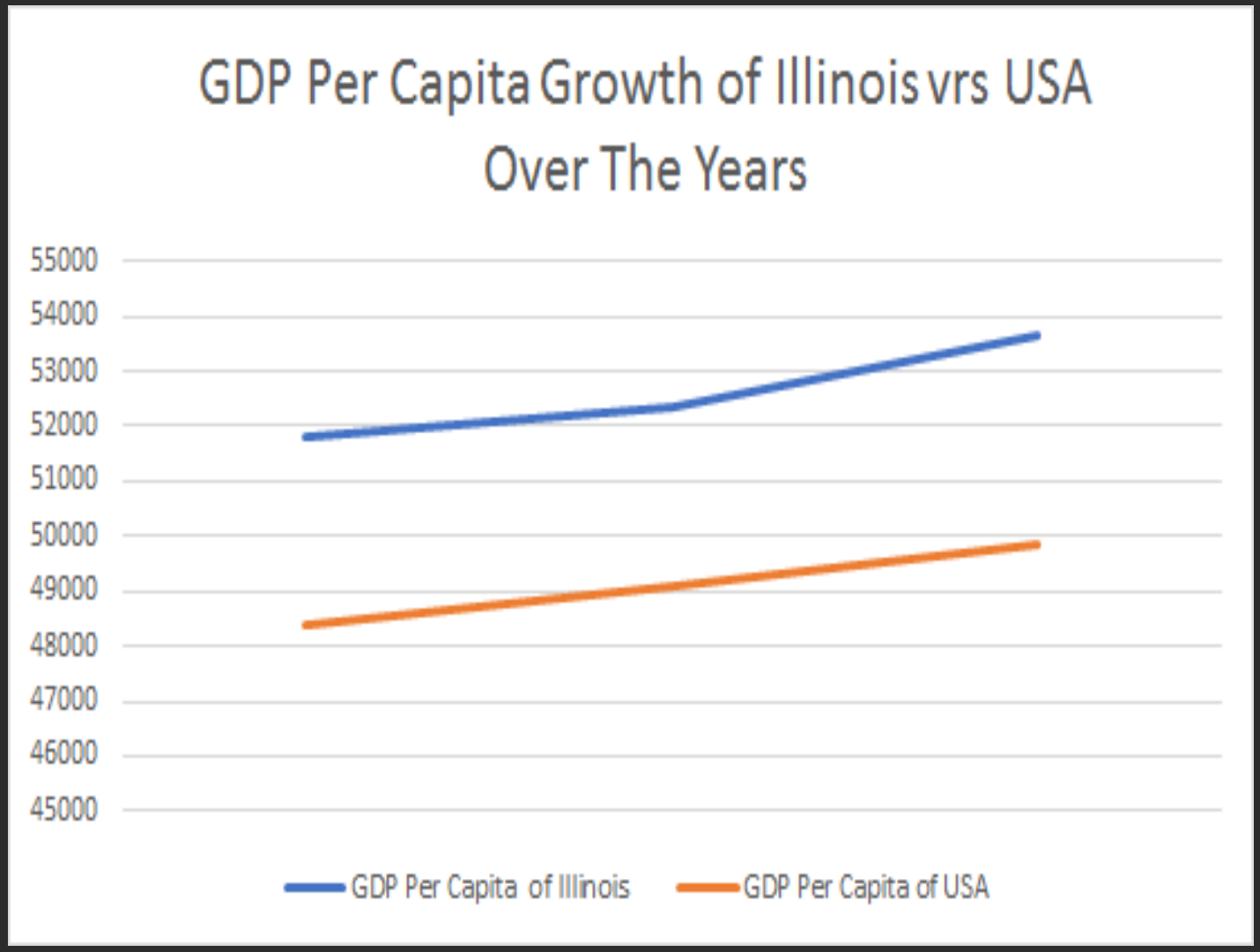
How this impacts the population



Comparison

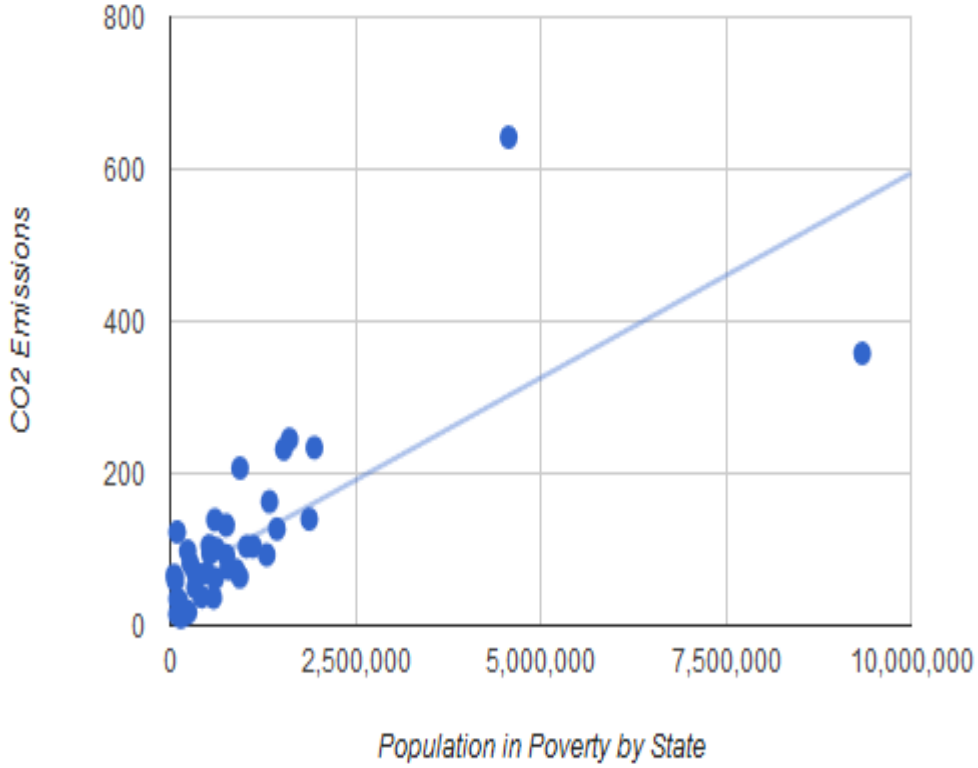

Growth of Earth and Population
Mass of Earth in Kilograms
5.972E+24
5.972E+24
5.972E+24
5.972E+24
5.972E+24
5.972E+24
5.972E+24
5.972E+24
1.2E+10
1E+10
8E+09
6E+09
4E+09
2E+09
0
Human population
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
Year

GDP Per Capita Growth



State rank*	State	Number of eligible high schools**	Gold medal schools (percent and total number)	Silver medal schools (percent and total number)	Total number of gold and silver medals	Percent of schools with gold and silver medals
1	IL	670	2.2% 15 Schools	12.2% 82 Schools	97	14.5%
2	MT	118	0.8% 1 School	5.1% 6 Schools	7	5.9%
3	ID	163	0% 0 Schools	5.5% 9 Schools	9	5.5%
4	MO	508	0.8% 4 Schools	3% 15 Schools	19	3.7%
5	IA	335	0% 0 Schools	3.3% 11 Schools	11	3.3%
6	KS	314	0% 0 Schools	3.2% 10 Schools	10	3.2%
7	LA	308	1.3% 4 Schools	1.6% 5 Schools	9	2.9%
8	MS	238	0% 0 Schools	1.7% 4 Schools	4	1.7%
8	ND	118	0% 0 Schools	1.7% 2 Schools	2	1.7%
10	NE	236	0%	0.8%	2	0.8%

CO2 Emissions



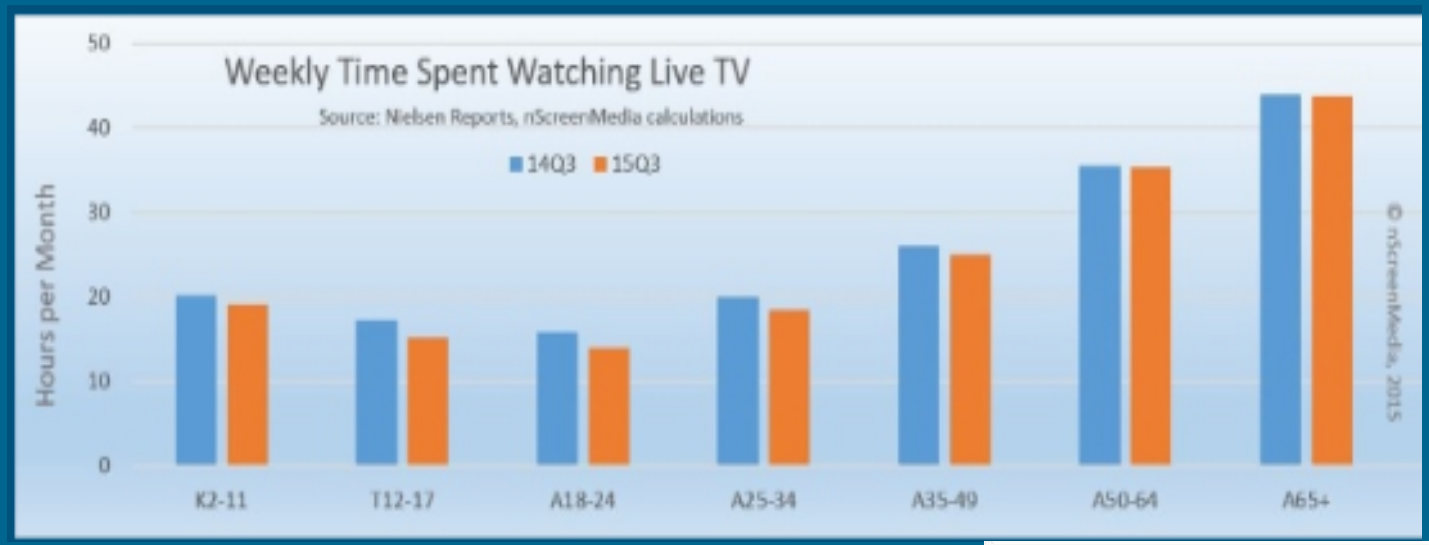
r	r^2	Slope	Y Intercept	Std. Err. of Estimate
0.7429	0.5519	0.000054	56.679853	75.9818

t	df	p		
			one-tailed	<.0001
7.02	40		two-tailed	<.0001

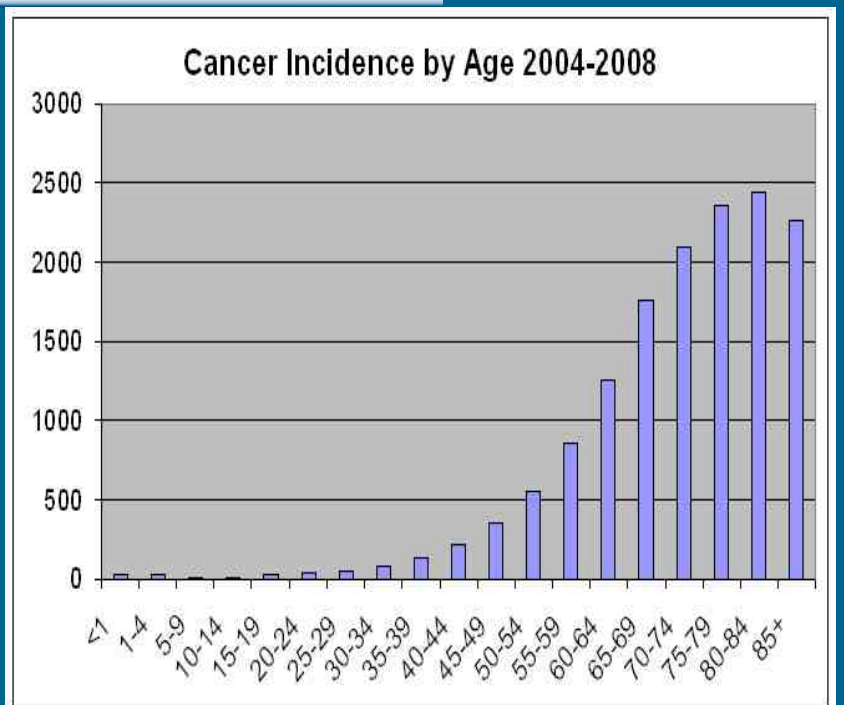
0.95 and 0.99 Confidence Intervals for rho

	Lower Limit	Upper Limit
0.95	0.567	0.854
0.99	0.497	0.878

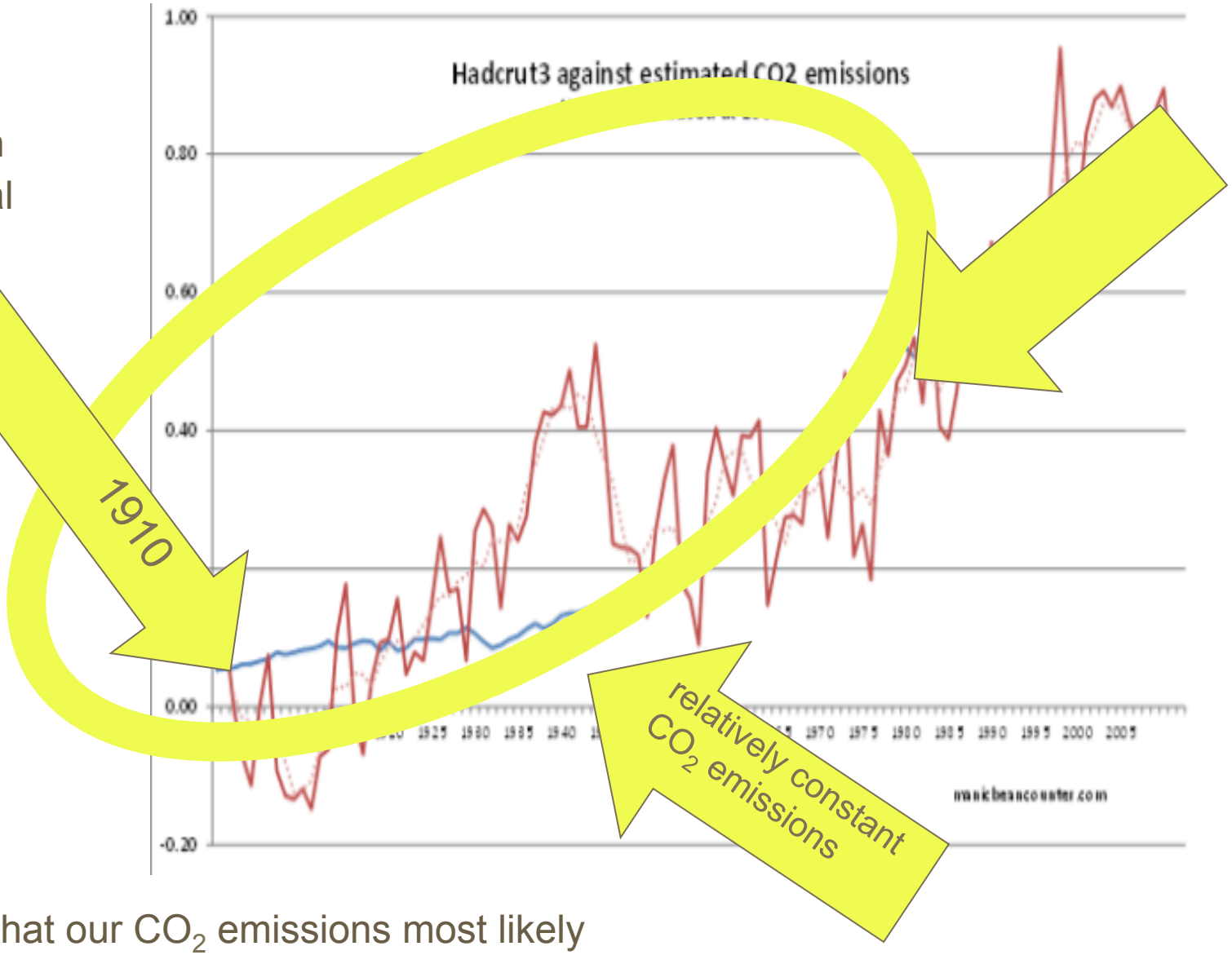
A Clear Correlation between TV Time and Cancer Rates



We can see an obvious, common, trend between TV watching time and cancer incidence.



As this graph shows, global warming started i
1910, wel
before CO_2 emissions started increasing.



This means that our CO_2 emissions most likely don't substantially contribute to climate change

The election and forecasting

- The 2016 election was remarkable for many things, but one was the polls' firm and nearly unanimous prediction of the opposite outcome
- As Pradeep Mutalik put it: the only person who correctly predicted the outcome of the election was Donald Trump
- Nate Silver (who gave Trump a 29% chance of winning) argues that this is within polling error
- Many questions remain
  - Here's one: Did James Comey's revelation affect the outcome of the election?
  - Evidence to support this is laid out in a much-cited piece in Vox
  - Most arguments here can actually go both direction; the truth is very hard to sort out

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Ambiguous statistics at work

The effect of Comey's late intervention into the election is also clear in the national polls. As neuroscientist Sam Wang showed, Clinton's margin over Trump falls dramatically in national polls directly after the Comey letter and never recovers. At the time, statistician Nate Silver noted that the Comey letter coincided with "a swing of about 3 points against her" — a massive swing in a tight election. These public polls are supported by internal polling from both campaigns suggesting that Comey was a massive blow to Clinton at a pivotal moment in the election.

Why does it matter if he's a neuroscientist? "Untouchable authority" fallacy.

He also said that it is unclear how much can be attributed to Comey, citing several other important factors

Nate Silver's plot looks different here

Sam Wang's plot shows a clear recovery. Also, Sam Wang gave Clinton a 99% chance of winning

If you follow the links, you discover that only the Democratic party did internal polling, and that they found Clinton recovered after a few days

http://www.vox.com/the-big-idea/2017/1/11/14215930/comey-email-election-clinton-campaign

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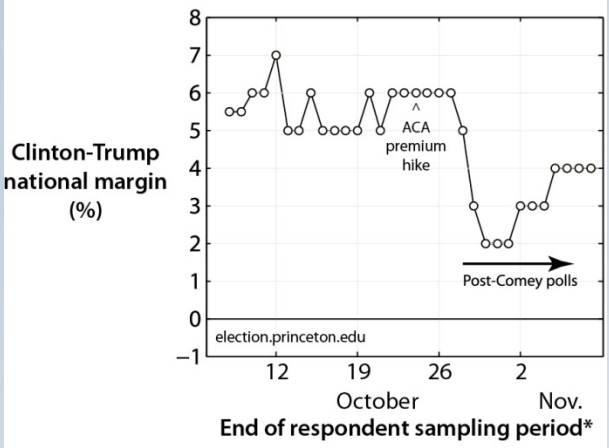
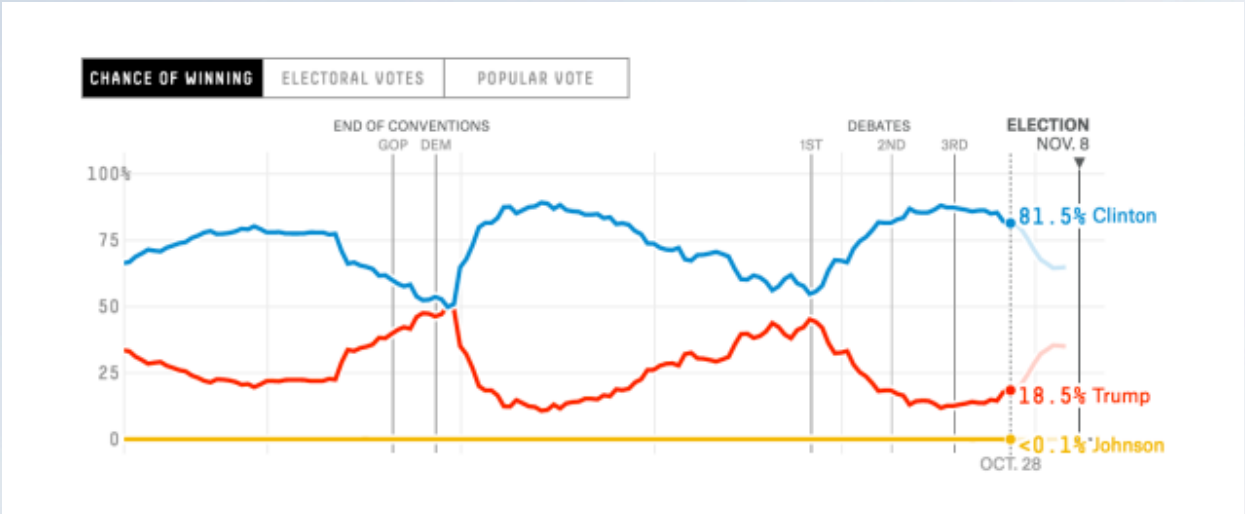
The trouble with polls



- Sam Wang's plot shows a dramatic drop

http://election.princeton.edu/2016/12/10/the-comey-effect/



- Nate Silver's looks much more gradual

https://fivethirtyeight.com/features/how-much-did-comey-hurt-clintons-chances/

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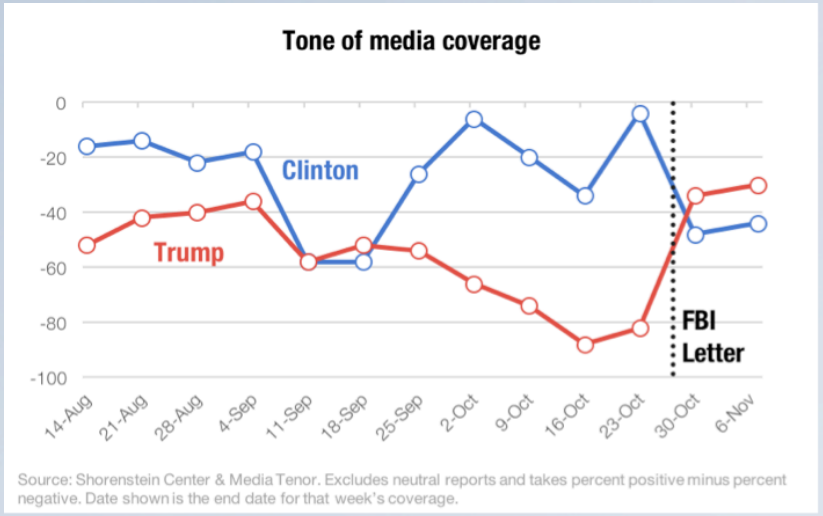
Ambiguity of interpretation



http://www.vox.com/the-big-idea/2017/1/11/14215930/comey-email-election-clinton-campaign

- This plot was used to show that negative media coverage damaged Clinton in the final days of the election
- However, the same plot shows that media coverage of Trump was consistently much more negative, so shouldn't it have damaged him more?

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Systemic polling error

- Another argument is an intrinsic failure in polling methodology
- Polls were off substantially in:
  - 2014 midterm Congressional elections
  - 2014 Scottish independence referendum
  - 2015 British Parliamentary elections
  - 2015 Israel Parliamentary elections
  - 2015 Kentucky governor election (off by 13%)
  - 2016 British exit vote
  - 2016 Congressional elections
- All were off in the same direction: they underestimated the conservative numbers

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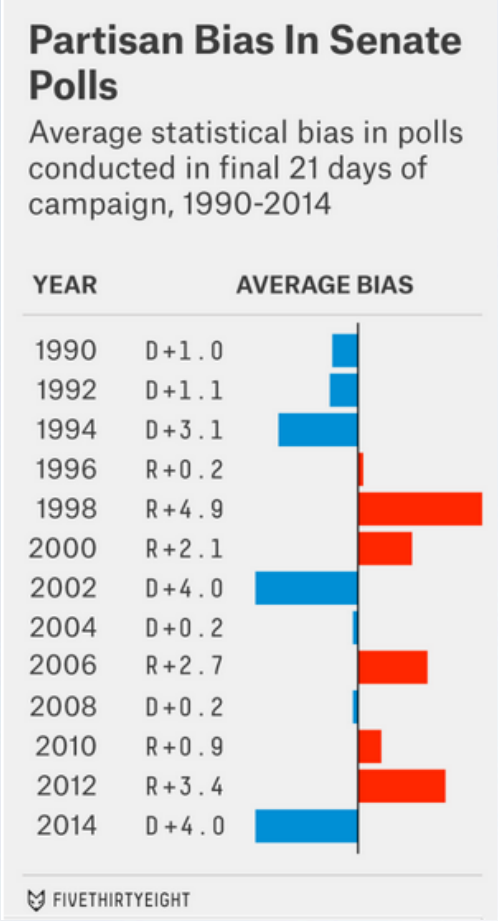
Can polls be trusted?

- Polls are often biased, but in different directions over time
- Nate Silver says there is good evidence for a “herding” effect in which polls tend to agree with each other, or with conventional wisdom



https://fivethirtyeight.com/features/the-polls-were-skewed-toward-democrats/

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The takeaway

- Polling is difficult and possibly untrustworthy
- No election can be reduced to a simple explanation
- The messiness of politics will probably never be explainable with scientific methodology
- All the same, statistics may help us make better choices
  - …Provided we understand the statistics